Nichole Embertson

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Subject: Follow Up Notes from 4/30 DOE Meeting

Project Partners,

First off, I wanted to thank everyone for their participation in the meeting on April 30 to hear about our Application Risk Management (ARM) System and our goals for reducing surface water, groundwater, and air pollution events associated with manure application. There was a lot of information presented, and due to time constraints, some important concepts and issues may not have been addressed adequately such as the composition of manure, early season application, and storage requirements. I apologize in assuming some of the background science as “common knowledge” among the participants, and I hope to expand on a few of those concepts so that you may better understand the link between manure and nitrate leaching potential. With a better understanding of these processes, I think it will become evident that our ARM tool will actually aid in *decreasing* groundwater leaching events along with runoff and volatilization events. Additionally, I realized that while I know many of you, I was remiss in not giving a more detailed bio to those who I have not had the pleasure of meeting.

Briefly, I would like to start by giving a background of the primary project team members. I (Nichole Embertson) joined the District in November 2008, not just as a nutrient planner, but to secure funding for projects to directly address solution oriented concepts and practices at the farm level. By working with other partner agencies, it is my goal to find ways to help farmers reduce their environmental impacts with practical, economical, and effective solutions. I acquired this perspective while doing research for my Masters at UC Davis and Doctorate at Colorado State University, both of which were in Animal Science with an emphasis in Environmental Management and a specialty in Air Quality. This combination of environmental systems knowledge, along with the understanding of production practices, uniquely suits me to address environmental issues at a farm level. Prior to joining WCD, I worked as a research scientist at Colorado State University conducting BMP research, working with farmers, regulatory agencies, and partner workgroups, and passing on that knowledge through lectures and conferences around the country. Other team member Chris Clark adds expertise as an EIT with an Animal Waste Systems emphasis. He has worked cooperatively on research projects with WSU and also with Shabtai Bittman, of Agriculture Canada to field proof the NLEAP nitrogen cycling software, which facilitates prediction and fate of manure applications to meet crop needs in our area. It is no exaggeration that he has worked with over 100 producers to develop and implement dairy nutrient management plans and has reviewed and interpreted yield data, soil, and manure tests for thousands of acres.

We created the ARM concept because of recognition of the limitations of the current model in meeting the needs of the farmer and protecting the environment. We were asked by agency and tribal representatives whether there was something we could do to improve the situation and so we came up with a tool that addresses surface runoff, groundwater, and air pollution risk. Pressed by the demands of running a dairy, producers need tools that they can easily use to assess the proper utilization of their nutrients while also avoiding environmental degradation. The more successful they are with this objective, the less likely it is that nutrients and pathogens will negatively impact surface and ground water. The ARM tool would interpret and give proper weight to the numerous biological, physical, and environmental factors necessary to achieve these overlapping goals. This project will provide the scientific data necessary to ensure the accuracy of the background calculations, and in doing so, ensure the efficacy of the tool. Additionally, it is important to note that *all* dairy operations are required to have a nutrient management plan (NMP) that outlines the appropriate use of nutrients based on desired environmental protection objectives, which will vary by producer and region. Within the NMP are guidelines and NRCS approved practices to meet all State and local laws such as the Critical Areas Ordinance and Manure Ordinance, as well as requirements for nutrient management (NRCS 590) which includes fall nitrate testing, P-index analysis and protection measures for surface and ground water. All NMPs are written so that animal numbers, estimated manure production and runoff collection, and land base are in balance with manure storage availability. Whatcom County has the strictest regulations and guidelines in the State, and we are proud to be progressive and responsive to the challenges that we face in this area.

Second, it seemed that not everyone was as immersed in the subject of manure and the nitrogen cycle as we were. Be thankful for that. However, in all seriousness, the composition and properties of manure and how nitrate is related to manure are fundamentally important concepts which must be addressed before we can entertain discussions about the timing of manure applications and potential nitrate leaching to groundwater. Of all the nutrients and compounds in manure, nitrogen accounts for approximately 0.5% of the total fresh manure content (this will vary with manure handling practices, amount of rainwater collected, and dairy animal nutrition). That is approximately 10-14 lbs / 1000 gal of dairy slurry (liquid manure). Of that total nitrogen content, about half is organic nitrogen and half is ammonium nitrogen (NH_4-N; combination of ammonium and ammonia). **Manure contains very little or no nitrate nitrogen** (nitrate comes from soil nitrification processes, not directly from cows nor manure storage lagoons). Once incorporated in soil, the organic-N portion of the manure is converted to NH_4^-N via mineralization. This is a slow process and is dependent on soil temperature, soil moisture, pH, manure composition, and incorporation rate in the soil. Approximately 60% of organic-N is available during the year it is applied. The remaining organic-N (~40%) is bound to soil particles and either becomes available in subsequent years or is lost via surface erosion (i.e. runoff); it is *not* lost via leaching. The remaining NH_4-N portion of the manure is either taken up by plants after application (minimal), volatilized as ammonia (NH_3), converted by soil microbes to nitrate (NO_3^-) via nitrification, immobilized or bound to negatively charged clay particles and soil organic matter (OM) when conditions are not conducive to nitrification. The amount of applied NH_4-N lost to volatilization is approximately 20-50% and depends on many factors including soil N availability, manure application method, ambient temperature, soil moisture, pH, and wind speed. After losses and direct plant uptake, the NH_4-N left in the manure (~30%) is available for nitrification and conversion to nitrate for subsequent plant uptake.

The conversion of NH_4-N to nitrate is dependent on several factors, but the most notable are soil temperature and soil moisture. At soil temperatures between 40° and 90°F (in top 12" of soil), soil microbes will convert NH_4-N to NO_{3^-} with peak conversion rate somewhere between those temperatures (max rate will vary based on many factors). If soil temperature is below 40°F or above 90°F, conversion rapidly drops off leaving NH_4^+ as the predominant nitrogen species left bound to the clay particles and soil OM. The grass growth curve is closely correlated to this nitrification rate curve, with maximum growth peaking in May/June and decreasing when temperatures are outside of the ideal range specified. This soil temperature/nitrification principle is important to understand when we are discussing early season spreading when soil temperatures are still cool (<= 40°F) and nitrate conversion and availability to growing plants is low, leaving organic-N and NH_4-N as the predominate N species in the soil. Conversely, in the late fall, an increase in nitrate conversion with optimal temperatures and rehydration of the soil profile, coupled with a reduction in manure N volatilization and plant uptake, can allow NO_3^- to be in excess of plant uptake and available for leaching when moved below the root zone with increased fall precipitation. Under the new fall application timing guidelines proposed by the ARM system (ceasing of manure application in September instead of October when rates are not necessarily agronomic), the leaching potential of applied manure would decrease. Additionally, if the soil becomes saturated and anaerobic due to high rainfall, poor infiltration, flooding, or a very high water table, and infiltration is unable to occur, nitrification will cease and anaerobic denitrification process will take over in the soil profile. During denitrification, available nitrate will be reduced to nitrous oxide (N_2O) or nitrogen gas (N_2) and lost to the air. This rate of loss accounts for approximately 10% of total N loss and typically occurs in saturated soils or after significant rain events.

Third, there seemed to remain a question about the application of manure to grass fields in the late winter (Jan/Feb) and the possible contribution to nitrate leaching to groundwater. It must be stated that this practice is limited and would only qualify for approximately 10% of the total planned acres in Whatcom County. Additionally, early season application is only available for select fields that have been deemed low risk under our comprehensive criteria analysis and have an agronomic need for N application. This is *not* an acceptable practice for emptying lagoons in the early season as an avoidance of proper storage. For those select, low risk fields and optimal times (soil temperature and weather conditions) that qualify, the application of manure to grass fields in the late winter (Jan/Feb) has been shown in scientific studies to have a benefit to crop growth and nutrient uptake, and does not promote nitrate transport to groundwater. This is primarily because the manure-N applied is bound to the soil particles as NH_4-N or organic-N, which do not undergo leaching. In fact, applying manure in the dry, cooler season can actually reduce runoff potential, volatilization losses via ammonia, and nitrate losses via nitrification by binding N to soil particles and conserving more nitrogen in the root zone of the plant. This is because after application, the manure NH_4-N will bind to the soil particles in a cation-anion exchange reaction (negatively charged particles ($soil^-$) are attracted to positively charges particles (NH_4^+)), the manure organic-N will mineralize at a very slow rate, and NO_3^- will be produced via nitrification in the top layer (6") of the soil when soil temperatures fluctuate above 40°F. This rate of conversion is comparable to the rate of uptake by the plant matter at that time of year. As the soil temperature begins to rise after February, and nitrification rates increase, nitrate will be readily taken up by the rapidly growing forage. Additional benefits to early season application include greater forage growth, which will take up more nutrients from the soil, an allowance to adjust application timing in a changing climate, and an increased opportunity to apply manure during an appropriate weather window when the crop can be supplied with nutrients effectively to meet nutrient needs. NOTE: This is not an alternative to having adequate storage capacity, but rather in addition to it. Unseasonal or changed climatic conditions could eliminate this window of application. However, applying earlier in the season generally means greater availability and utilization by crops, which can reduce or eliminate excess after harvest thereby affording groundwater more protection against winter leaching.

Fourth, last week I spoke a lot about agronomic application rates and supplying nutrients to crops at only the necessary rates to achieve crop yield goals. While I spoke mainly in the context of manure application to grass during my presentation, I would like to touch on the issue of applying manure to corn ground. In the case of application of manure to *bare* ground following corn harvest in the fall, this practice is not allowed in Whatcom County. Even if a relay or cover crop has been planted in conjunction with the corn, which is what is always recommended, application of manure following harvest is very unusual. This is because typically, enough N has been applied to the crop in the spring to get it through the growing season with some left over in the fall due to mineralization. This remaining amount is determined via a fall nitrate test, which all producers conduct on their farms fields yearly. While it may give variable results depending on when/how it is taken, the fall nitrate test shows not only how much nitrate is left over at the end of the year (test typically done in October), but allows the producer to readjust manure application rates the following year to reduce excess soil nitrate.

Fifth, a statement was made that some producers empty their lagoons in the fall independent of agronomic considerations. We expect that this is because they have learned the severe consequences of running out of storage. This practice is not condoned nor is it in any dairy nutrient management plans written by WCD. Our plans call for adequate storage to get through non-application periods. Adequate storage will vary and is based on, among other considerations, animal numbers, estimated manure production, and cropping system and can vary from 4 months to 9 months. The value of 6 months has been used in the past as a starting point and general guideline, but individual evaluation by farm is more appropriate. In fact, excess storage may actually enable a producer to continue practices which are inappropriate for their inventory, land base, and/or crop rotation. It is often poor management that is the resulting cause of in inordinately high manure levels in lagoons in the spring. There are other significant associated problems with this solution. By having greater volume and surface area of stored manure and for longer periods, there is an increased risk of a larger scale impact from a lagoon failure. The greater surface area increases methane, odor, and ammonia volatilization potential. Additionally, more rain water is collected, which dilutes the nutrient concentration of the manure and increases application volume to reach agronomic rates. This means the producer will have to apply more volume (gal) per acre, which increases runoff potential, increases the cost of transport and pumping, and demands greater energy use. For these reasons, we believe that increased storage alone is not the solution and that undue reliance upon storage should be avoided. Fostering nutrient uptake and utilization throughout the year is superior in comparison. The ARM system will provide the logic model to ensure that is the case.

Thank you for your continued interest in our project. We appreciate your constructive feedback and the opportunity to educate. Some details of the addressed principles were simplified in order to avoid writing a book, so please let me know if I can expand on any of these concepts further. A further review of the nitrogen cycle and winter time soil processes might help add understanding to these concepts. If you would like references to additional materials to do this, please let me know.

Cheers,

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